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(54) [Title of the Invention]

Manufacturing Method of Electroluminescent Element

(57) [Abstract]

[Object]

To provide a manufacturing method of an electroluminescent element which enables to use a conjugate system high molecular which is excellent in charge injecting and transporting properties and has a high thermal-stability, as a charge transporting layer of the electroluminescent element.

[Means for Resolution]

A hole transporting layer 13 is formed of a conjugate system high molecular by electrolytic polymerization over the surface of a transparent electrode 12 formed of ITO. After that, a light-emitting layer 14, an electron transporting layer 15, and a metal electrode 16 are formed in order. By forming the hole transporting layer 13 by electrolytic polymerization, it becomes possible to use a conjugate system high molecular having excellent injecting and transporting properties of charge and a high thermal-stability, as a charge transporting layer of an electroluminescence element. Thus, an electroluminescence element having an excellent property can be manufactured.

[Scope of Claim]

[Claim 1]

A manufacturing method of an electroluminescence element having a hole transporting layer and an electron transporting layer between an anode electrode and a cathode electrode which face with each other,

characterized in that at least one of the hole transporting layer and the electron transporting layer is formed to cover at least one of the anode electrode and the cathode electrode by an electrochemical method.

[Claim2]

The manufacturing method of the electroluminescence element according to Claim 1, characterized in that at least one of the hole transporting layer and the electron

transporting layer is polyocthylthiophene.

[Claim 3]

The manufacturing method of the electroluminescence element according to Claim 1, characterized in that a light-emitting layer is formed between the hole transporting layer and the electron transporting layer.

[Claim 4]

The manufacturing method of the electroluminescence element according to Claim 1, characterized in that at least one of the anode electrode and the cathode electrode is in plural, and at least one of the hole transporting layer and the electron transporting layer is in plural in accordance with at least one of the anode electrode and the cathode electrode and they are separated with each other.

[Claim 5]

The manufacturing method of the electroluminescence element according to any one of Claims 1 to 4, characterized in that at least one of the hole transporting layer and the electron transporting layer has a thickness of 1 to 50 nm.

[Claim 6]

The manufacturing method of the electroluminescence element according to any one of Claims 1 to 5, characterized in that at least one of nitrogen drying treatment and reduced-pressure heating-drying treatment is conducted to at least one of the hole transporting layer and the electron transporting layer after being formed.

[Claim 7]

The manufacturing method of the electroluminescence element according to any one of Claims 1 to 6, characterized in that the electrochemical method is an electrolytic polymerization method in which the anode electrode or the cathode electrode is soaked in a polymerization solution containing a forming material of a hole transporting layer or an electron transporting layer, and after that, voltage is applied to the electrode so that the hole transporting layer or the electron transporting layer is formed to cover, over the electrode.

[Detailed Description of the Invention]

[0001]

[Industrial Field of the Invention]

The present invention relates to a manufacturing method of an electroluminescence element, and it specifically relates to a manufacturing of an organic electroluminescence element.

[0002]

[Related Art]

Conventionally, a structure shown in FIG. 11 is known as this kind of electroluminescence element. As shown in this figure, this electroluminescence element has a structure in which a transparent electrode (hole injecting electrode) 2 formed of, for example, ITO (indium tin oxide) is formed over a transparent substrate 1 formed of, for example, glass and over the transparent electrode 2, a hole (hole) transporting layer 3, a light-emitting layer 4, an electron transporting layer 5, and a metal electrode 6 are stacked in order. The hole transporting layer 3, the light-emitting layer 4, and the electron transporting layer 5 in this electroluminescence element each are formed to be a thin film shape by vacuum depositing an organic material. With the use of the organic material, an excellent element property is obtained. In particular, as a low molecular organic material, TPD which is a diamine-based material shows a high hole transporting property, and is used as a hole transporting layer material for most of the light-emitting elements with high luminance in the present. Further, a light-emitting element for which an organic high molecular material is used as a quite different material is considered.

[0003]

[Problems to be solved by the Invention]

However, the above-described TPD has a low thermal-stability, and a defect or high resistance is generated due to recrystallization of a thin film in accordance with continuous light emission. Thus, it is difficult to obtain lifetime or stability as a product. Although an improvement of the charge injection interface by plasma treatment, development of a starburst amine-based material having a better thermal-stability, or the like have been attempted, a sufficient result has not been

obtained at the present.

[0004]

Light-emitting element using an organic high molecular material is called a high molecular LED, and mostly has two roles of a charge transporting layer such as a hole transporting layer or an electron transporting layer, and a light-emitting layer, with a single layer. At the present time, the light-emitting element using a low molecular material is superior to the light-emitting element using an organic high molecular material in the point of the primary performance of luminance, efficiency, or the like. However, it is considered that the light-emitting element using an organic high molecular material is superior to the light-emitting element using a low molecular material in the point of stability, or the like.

[0005]

Such an organic high molecular material is included in the category of a so-called π-conjugated high molecular which has been studied as a conductive high molecular. That has a strong main chain, and is insoluble and unmelting in many cases. Thus, there was a problem that solvent was required to be solubilized by adding a long side chain when that material was used for coating formation of a thin film. Further, there was a problem that a transporting property and a thermal-stability of charge were lowered when adding a long side chain as above. Moreover, when a hole transporting layer is formed in an anode electrode, or an electron transporting layer is formed in a cathode electrode, the light-emitting intensity becomes extremely low if the film thickness is too thick. Thus, it is required to be formed thin as much as possible; however, it is difficult to form a film with a uniform thickness by a coating method. Moreover, a charge transporting layer becomes island-like shape over the electrode, if it is formed with a small thickness. Thus, in the case where a light-emitting layer is formed by providing a light-emitting material in the charge transporting layer, or a light-emitting layer is provided over the charge transporting layer, light-emitting efficiency is low, variation in display is generated, or the like. In addition, a multiple tone display is possible since such a light-emitting element emits light with the

light-emitting intensity in accordance with an electric field; however, in the case of providing it for a plurality of high-definition pixels in matrix, there was a problem that it becomes difficult to conduct an excellent multiple tone display, since a pixel pitch is short so that an electric field of the adjacent pixel is affected, if a charge transporting layer is directly formed over a plurality of electrodes in succession. Thus, a charge transporting layer is patterned in accordance with a pixel; however, the charge transporting layer is deteriorated by a photoresist process, or the like. Therefore, a problem that the light-emitting efficiency is low and light-emitting lifetime is short was generated. It is an object of the present invention to consider a means for obtaining a manufacturing method of an electroluminescence element which makes it possible to use a conjugate system high molecular which is excellent in injecting and transporting properties of charge and has a high thermal-stability as a charge transporting layer.

[0006]

[Means for Solving the Problem]

The invention according to Claim 1 is, in the manufacturing method of an electroluminescence element having a hole transporting layer and an electron transporting layer between an anode electrode and a cathode electrode which face with each other, characterized in that at least one of the hole transporting layer and the electron transporting layer is formed to cover at least one of the anode electrode and the cathode electrode by an electrochemical method. The invention according to Claim 2 is characterized in that at least one of the hole transporting layer and the electron transporting layer is polyocthylthiophene. The invention according to Claim 3 is characterized in that a light-emitting layer is formed between the hole transporting layer and the electron transporting layer. The invention according to Claim 4 is characterized in that at least one of the anode electrode and the cathode electrode is provided in plural, and at least one of the hole transporting layer and the electron transporting layer is provided in plural in accordance with at least one of the anode electrode and the cathode electrode and they are separated with each other. The invention according to Claim 5 is characterized in that at least one of the hole

transporting layer and the electron transporting layer has a thickness of 1 to 50 nm. The invention according to Claim 6 is characterized in that at least one of nitrogen drying treatment and reduced-pressure heating-drying treatment is conducted to at least one of the hole transporting layer and the electron transporting layer, after being formed. The invention according to Claim 7 is characterized in that the electrochemical method is an electrolytic polymerization method in which the anode electrode or the cathode electrode is soaked in a polymerization solution containing a forming material of a hole transporting layer or an electron transporting layer, and after that, voltage is applied to the electrode so that the hole transporting layer or the electron transporting layer is formed to cover, over the electrode.

[0007]

In the present invention, it becomes possible to use a conjugate system high molecular material which is excellent in injection of holes or electrons and a charge transporting property and has a high thermal-stability, since a hole transporting layer or an electron transporting layer is formed with the use of an electrolytic polymerization reaction method. Therefore, in the present invention, it becomes possible to lower the voltage at the start of emission of an electroluminescence element, and improve the light-emitting efficiency or luminance. Further, it becomes possible to extend the lifetime of an element because of the high thermal-stability.

[0008]

[Embodiment Mode of the Invention]

Hereinafter, the manufacturing method of the electroluminescence element related to the present invention is described in detail based on embodiment modes shown in figures.

(Embodiment Mode 1)

FIGS. 1(A) to 1(E) are cross-sectional views of a process which describes Embodiment Mode 1 of the present invention. First, in this embodiment mode, a transparent electrode 12 formed of ITO or zinc oxide aluminum having a sheet resistance of approximately 60 Ω/cm^2 is patterned to be formed as an anode electrode

over a transparent substrate 11 formed of, for example, glass, or synthetic resin (size; 15 mm × 75 mm, a thickness of 0.7 mm), as shown in FIG. 1(A). Next, a hole (hole) transporting layer 13, as shown in FIG. 1(B), is formed in the surface of the transparent electrode 12 over the transparent substrate 11 with the use of an electrolytic polymerization apparatus 20 as shown in FIG. 2 in this manner.

[0009]

The electrolytic polymerization apparatus 20 includes a curing tank 22 having a polymerization solution 21 as shown in FIG. 2, and a counter electrode 23, a reference electrode 24 and the transparent substrate 11, which are each connected to a power source 25, are soaked in the polymerization solution 21. Here, the transparent electrode 12 over the transparent substrate 11 becomes an action electrode. The polymerization solution 21 includes solvent, supporting electrolyte, and monomer or oligomer to be a hole transporting layer by polymerization, or the like. By conducting electrolytic polymerization with the use of such an electrolytic polymerization apparatus 20, the hole transporting layer 13 formed of a conjugate system high molecular can be formed over only the surface of the transparent electrode 12. After that, treatment such as dedoping, cleaning, drying, or annealing, is conducted to the hole transporting layer 13 formed by electrolytic polymerization, as required.

[0010]

As the monomer, at least one or more from the followings can be used: alkylthiophene such as thiophene and 3-n-hexylthiophene; a conductive organic material such as benzene, phenylenevinylene, thienylen vinylene, pyrrole, furan, aniline, fluorene, and carbazole; a derivative of them; arene such as styrene and allyl benzene; a derivative of them; and a metal complex of them.

[0011]

As the supporting electrolyte, the following can be used: salt such as sodium perchlorate (sodium perchlorate), lithium perchlorate, tetrabuthylammonium perchlorate, and tetrabuthylammonium tetrafluoroborate; another base or acid; and the like.

[0012]

As the solvent, one of the followings or a plurality thereof mixed can be used as an appropriate solvent for solving the above-described monomer and supporting electrolyte: water, acetonitrile, dimethylsulfoxide, dimethylformamide, nitromethane, tetrahydrofuran/propylene carbonate, and the like.

[0013]

Next, a light-emitting layer 14 is formed over the entire surface of the transparent substrate 11 in which the hole transporting layer 13 is formed by a method such as a vacuum evaporation method and a coating method, as shown in FIG. 1(C). As the light-emitting layer 14, a dispersive light-emitting layer of Alq_3 (tris(8-quinolil)aluminum complex), or a low molecular or high molecular can be used. Next, an electron transporting layer 15 is formed over the light-emitting layer 14 by a vacuum evaporation method or a coating method, as shown in FIG. 1(D). The electron transporting layer 15 is formed of, for example, an oxadiazole-based compound, besides Alq_3. After that, a metal electrode 16 as a cathode electrode is formed over the electron transporting layer 15 by a vacuum evaporation method. As the metal electrode 16, for example, indium (In), magnesium (Mg), aluminum (Al), calcium (Ca), lithium (Li), gold (Ag), or an alloy of them can be used. Moreover, an alkali metal element may be contained in them.

[0014]

The electrolytic polymerization method in Embodiment Mode 1 of this invention is shown in FIG. 6, and described hereinafter. In this embodiment mode, it is characterized that a hole transporting layer 42 is formed of poly octhylthiophene (hereinafter, called PAT8) over a transparent electrode 41 formed of ITO as an anode electrode, as shown in the same figure. For forming the hole transporting layer 42 of the PAT8, the electrolytic polymerization apparatus 20 shown in FIG. 2 is used. In the polymerization solution 21, 0.1 to 1 M of octhylthiophene as the monomer, acetonitrile as the solvent, and 0.1 to 1 M of sodium perchlorate as the supporting electrolyte are employed. The transparent substrate 11 provided with a plurality of patterned transparent electrodes 12 on the surface is retained by a supporting member 27

connected to a wire 26 of the power source 25. Below the transparent substrate 11, the curing tank 22 filled with the polymerization solution 21 is disposed, and the counter electrode 23 formed of platinum and the reference electrode 24 formed of Ag/AgC1 through a salt bridge, which are connected to the power source 25, are disposed in the polymerization solution 21. The power source 25 is structured by a potentiostat (control power source) and a coulomb meter (electric quantity measure).

[0015]

Here, the transparent substrate 11 falls down with the supporting member 27, and the transparent electrode 12 is soaked in the polymerization solution 21 in the curing tank 22. Then, when voltage of a prescribed value is applied to the transparent electrode 12 from the power source 25 through each of the counter electrode 23, the wire 26, and the supporting member 27, the monomer in the polymerization solution 21 is polymerized in the transparent electrode 12 by electrolytic polymerization so that a hole transporting layer 13A is formed with a uniform thickness over the surface of the transparent electrode 12. After forming the hole transporting layer 13A, the transparent substrate 11 is raised in accordance with raise of a supporting member 26 from the curing tank 22, and drying treatment is conducted by nitrogen flow and vacuum heating with a temperature of 150°C. As the light-emitting layer 43, bisnaphtyloxadiazole (BND) and coumarin 6 are diffused in polyinylcarbazole (PVCz), and it is formed by a dip-coating method. A metal electrode 44 is formed by evaporating aluminum. In this embodiment mode, the thickness of the hole transporting layer 13 formed of PAT8 by an electrolytic polymerization reaction is approximately 10 to 500 Å, and the thickness of the light-emitting layer 14 is set to be approximately 500 to 600 Å. The diameter of the light-emitting portion is set at 4 mm.

[0016]

Next, by applying forward bias to an electroluminescence element manufactured in this manner as shown in FIG. 6 (A) and an electroluminescence element without the hole transporting layer 42 formed of PAT 8 as shown in FIG. 6 (B), a bright green light-emission can be obtained from both of the elements. The green

emission spectrum is substantially equal to fluorescence spectrum of the coumarin 6 which is dissolved in the methanol solvent, and the emission is considered as the emission from the coumarin 6 due to recombination of holes and electrons.

[0017]

FIG. 7 shows the voltage-luminance characteristic of elements with and without the layer formed of PAT8 (this embodiment mode). A mark (a)* in FIG. 7 shows a characteristic curve of the element to which drying treatment by vacuum heating with a temperature of 150°C and nitrogen flow is performed, a mark (a) shows a characteristic curve of the element to which the above drying process is not conducted, and a mark (b) shows a characteristic curve of the element to which the electrolytic polymerization layer (PAT8) is not provided. The element without the PAT8 layer has an emission-starting voltage of approximately 13 V and the maximum luminance of approximately 10 cd/m^2. On the other hand, the brighter light-emission can be confirmed at 8 V in this embodiment mode, and the light-emitting intensity is approximately 100 cd/m^2. In this manner, by interposing the PAT8 layer (hole transporting layer 42) between the ITO layer (transparent electrode 41) and the PVCz layer (light-emitting layer 43), the emission-starting voltage is reduced by 5 V and the light-emitting intensity becomes approximately 10 times higher. In particular, the drying process of the PAT8 improves the EL characteristic drastically as shown in (a)* of FIG. 7. The light-emission starts at 8 V which is lower than the element shown in (b) of FIG. 7, and the light-emitting intensity is reached to 700 cd/m^2 which is 70 times higher.

[0018]

FIG. 8 shows dependency of V-L characteristic to a charge quantity (film thickness) of PAT8. In the case where the PAT8 layer formed with the constant current of 80 μA/cm^2 by changing time, different characteristics can be obtained. The case of obtaining the best characteristic is the one with overlapping time of one minute (film thickness is 20 nm). The practical light-emitting intensity is obtained when the film thickness of PAT8 is 1 to 50 nm, preferably 10 to 40 nm, and more preferably 15 to 25

nm. If the overlapping time is more than 1 minute, the emission-starting voltage gradually increases and the light-emitting intensity decreases. It is considered that this is because the resistance between the ITO layer and the Al layer increase. However, in the case of the short overlapping time of 30 seconds and low resistance of PAT8, polymerization is insufficient and an island-like transporting layer is formed over the electrode, so that the light-emitting efficiency is lowered. Thus, the characteristic is almost the same as the case without PAT8, with the high emission-starting voltage and the low luminance.

[0019]

FIG. 9 shows a transmission spectrum of the one in which the PAT8 layer is formed over the ITO layer. In addition, FIG. 10 shows a light-emitting spectrum of the element using PAT8 (this embodiment mode). The EL spectrum is very similar to the PL spectrum of the coumarin 6, and the light-emitting spectrum does not change due to absorption of the PAT8 film. Therefore, it is understood that the PAT8 layer functions as a transparent hole transporting layer.

[0020]

As described above, this embodiment mode can achieve the high luminance and the low emission-starting voltage, since the PAT8 controlled to be the optimized thickness by electrolytic polymerization is used as a hole transporting layer by carrying out drying treatment. The element characteristic depends on the charge quantity in electrolytic polymerization. Thus, the EL characteristic can be improved by controlling various parameters in accordance with electrolytic polymerization.

[0021]

The manufacturing process of Embodiment Mode 1 is explained above. According to this embodiment mode, the conjugate system high molecular material, which is excellent in hole injecting and transporting properties and has a high thermal-stability, can be used for the hole transporting layer 13. Therefore, in this embodiment mode, the emission-starting voltage can be made lowered, and the light-emitting efficiency or luminance can be improved. Moreover, in this

embodiment mode, lifetime of the element can be lengthened since a thermal-stability is high. In this embodiment mode, the hole transporting layer 13 is made a single-layer; however, a structure of stacking layer in which the hole transporting layer 13A formed by the electrolytic polymerization reaction and the hole transporting layer 13B formed of low molecular organics may be employed, as shown in FIG. 3.

[0022]

(Embodiment Mode 2)

FIGS. 4(A) to 4(E) are cross-sectional views of a process which describes Embodiment Mode 2 of the present invention. First, in this embodiment mode, as shown in FIG. 4(A), for example, a metal film formed by an evaporation method or a spattering method is patterned to form a metal electrode 32 as a cathode electrode over an insulating substrate 31 formed of, for example, epoxy resin, polyimide resin, ceramic, fibrous glass, or a compound of them. As the material of the metal electrode 32, for example, indium (In), magnesium (Mg), aluminum (Al), calcium (Ca), lithium (Li), gold (Au), or the like, or an alloy of them is employed; however, a transparent material formed of a metal oxide having a low work function, or the like may also be employed as the material.

[0023]

An electron transporting layer 33 is formed in the surface of the metal electrode 32 by using the electrolytic polymerization apparatus 20 shown in FIG. 2. In this embodiment mode also, as the monomer, a conductive high molecular material such as thiophene, alkylthiophene, benzene, pyrrole, furan, aniline, florene, and carbazole; a derivative of them, arene such as styrene and allylbenene; a derivative of them; a metal complex of them; or the like can be used. Moreover, as the supporting electrolyte, a salt such as sodium perchlorate, lithium perchlorate, tetrabutylammonium perchlorate, and tetrabutylammonium tetrafluoroborate; another base or acid, or the like can be used. Further, as the solvent, one of the followings or a plurality of them mixed can be employed as the proper solvent which dissolves the above-described monomer and supporting electrolyte: water, acetonitrile, dimethyl sulfoxide, dimethylformamide,

nitromethane, tetrahydrofuran, or the like.

[0024]

Next, the light-emitting layer 34 is formed using a method such as a vacuum evaporation method or a coating method over the entire surface. As the light-emitting layer 34, a dispersive light-emitting layer of Alq_3 (tris(8-quinolil)aluminum complex), or a low molecular or high molecular can be employed.

[0025]

After that, a hole transporting layer 35 is formed by, for example, a vacuum evaporation method, a coating method, or the like over the light-emitting layer 34. As the material of the hole transporting layer 35, TPD, diamine-based compound, starburst amine-based compound, or the like can be employed. Next, a transparent electrode 36 is formed of ITO as an anode electrode over the organic layers. In this manner, manufacturing of an electroluminescence element of this embodiment mode is completed.

[0026]

As described above, in this embodiment mode, by forming the electron transporting layer 33 by using the electrolytic polymerization reaction, the conjugate system high molecular which is excellent in the electron injecting and transporting properties and has a high thermal-stability can be used which has not been used conventionally. Thus, decrease of the emission-starting voltage, improvement of the light-emitting efficiency or luminance, and advancement of stability of the electroluminescence element can be realized. The electron transporting layer 33 may be structured by stacking the electron transporting layer 33A formed by electrolytic polymerization and the electron transporting layer 33B formed of low molecular organics, as shown in FIG. 5.

[0027]

Each embodiment mode is described above; however, this invention is not limited to this, and various modifications in design associated with the scope of the structure are possible. In each embodiment mode above, an electrolytic

polymerization method is used as an electrochemical method; however, the present invention is not limited to this, and a method such as an electrolytic synthesis method, an electrodeposition coating method, or an electrophoresis method, can also be employed. In each the embodiment mode above, the description was made of a light-emitting element with a so-called double hetero structure in which a light-emitting layer, a hole transporting layer, and an electron transporting layer are provided as different layers respectively; however, a light-emitting element with a so-called single hetero structure in which either of a hole transporting layer or an electron transporting layer is made a light-emitting layer can be applied similarly. In addition, a transparent electrode may be processed with a silane-based or titanate-based coupling agent before electrolytic polymerization in order to improve adhesiveness between the transparent electrode and the hole transporting layer. For the electron transporting layer, a metal having a low work function is used in order to improve the light-emitting efficiency; however, in the case of forming the electron transporting layer over this by an electrolytic polymerization method, it is required to apply voltage which does not deteriorate an electron transporting layer due to oxidization as an electrode. The anode electrode and cathode electrode may be formed in a stripe shape, and an electrode being contacted with a charge transporting layer formed by the electrolytic polymerization may be formed in matrix and a switching element such as a TFT is each connected and the other electrode maybe formed one-piece to perform an active driving. In each embodiment mode above, the electroluminescence element which emits green light with the coumarin-based fluorescence pigment employed as the pigment included in the light-emitting layer is described; however, the present invention is not limited to this, and one or more kinds of perylene-based, oxazole-based, oxazine-based, naphthalene-based, quinolone-based, or the like and its derivative fluorescence pigment, or cation-based, and anion-based may also be employed in order to emit a different color or a plurality of colors without limiting to this.

[0028]

[Effect of the Invention]

As described above, it is obvious that the present invention provide an effect to make it possible to use a conjugate system high molecular which is excellent in charge injecting and transporting properties and has a high thermal-stability, as a charge transporting layer of an electroluminescence element.

[Brief Description of the Drawing]

[FIG. 1] (A) to (E) are cross-sectional views of a process which describe Embodiment Mode 1 of the present invention.

[FIG. 2] is an explanation drawing of an electrolytic polymerization apparatus.

[FIG. 3] is a perspective view showing a modified example of Embodiment Mode 1.

[FIG. 4] is a cross-sectional view of a process of Embodiment Mode 2.

[FIG. 5] is a perspective view showing a modified example of Embodiment Mode 2.

[FIG. 6] (A) is an explanation view showing Embodiment Mode 1, and (B) is an explanation view showing a comparative example.

[FIG. 7] is a graph showing a relationship between light-emitting intensity and voltage of Embodiment Mode 1 having a PAT 8 layer and a comparative example without PAT 8.

[FIG. 8] is a graph showing a relationship between light-emitting intensity and voltage due to a difference in the electrolytic polymerization time of a hole transporting layer.

[FIG. 9] is a graph showing a relationship between transmission efficiency and wavelength of Embodiment Mode 1.

[FIG. 10] is a graph showing a relationship between light-emitting intensity and wavelength of Embodiment Mode 1.

[FIG. 11] is a perspective view showing a structure of a conventional electroluminescence element.

[Description of the Numerals]

12: transparent electrode

13: hole transporting layer

14: light-emitting layer

15: electron transporting layer

16: metal electrode

20: electrolytic polymerization apparatus

32: metal electrode

33: electron transporting layer

34: light-emitting layer

35: hole transporting layer

36: transparent electrode